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(54) Scanning system with adjustable light output and/or scanning angle.

(57) The invention provides a method and a device for reading coded indicia such as bar code symbols which is operable in both a low power mode and a high power mode in order to prolong the operational lifetime of the semiconductor light source.

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SCANNING SYSTEM WITH ADJUSTABLE LIGHT OUTPUT AND/OR SCANNING ANGLE

BACKGROUND OF THE INVENTION

Field of the Invention

The invention generally relates to laser scanner systems based upon semiconductor light sources for reading indicia of different light reflectivity such as bar code symbols, and more particularly, to scanner systems in which adjustment of the intensity or spatial coverage of the beam is utilized to effect the detection and reading of symbols.

Description of the Prior Art

Various types of laser scanning systems are known in the prior art that read bar code symbols. Bar code symbols are applied to a label or surface of an article to form digital representations of information that are used to identify the article or other characteristics thereof. The bar code symbol itself is a coded pattern of indicia comprised of a series of bars of various widths spaced apart from one another to bound spaces of various widths. A laser scanner reads the symbol and decodes it into the digital representation representing the encoded information.

Various types of scanner systems are exemplified by U.S. Pat. Nos. 4,251,798; 4,360,798; 4,369,361; 4,387,297; 4,593,186; 4,496,831; 4,409,470; 4,460,120; 4,607,156 and 4,673,803--all of such patents being owned by the assignee of the instant invention and being incorporated by reference herein. Such scanners have generally been designed to read bar code symbols, particularly of the Universal Product Code (UPC) type, and operate at a certain working or reading distance from the symbol at a hand-held or stationary position.

Typically, a scanner includes a light source such as a laser or semiconductor device that generates a light beam which is optically modified to form a beam spot of a certain size. It is preferred that the beam spot size be relatively small, generally the same as or less than the minimum width between regions of different light reflectivity, i.e. the bars and spaces of the symbol. However, in practice it is not actually necessary that the spot size be so limited. The relative size of the bars and spaces is determined by the type of coding used to represent characters, as is the actual size of the bars and spaces. The number of characters per inch r presented by th bar code symbol is referred to as the density of the symbol.

The beam is directed by optical compon nts along a light path toward a target that includes a bar code symbol on the surface. A scanning component may either sweep the beam spot across the symbol and trace a scan line across and past the symbol, or scan the field of view of the photodetector, or do both. A scanner also includes a sensor or photodetector. The photodetector has a field of view extending across and slightly past the symbol and functions to detect light of variable intensity reflected off the symbol. The photodetector generates electrical signals representative of the sequence of bars and spaces in the symbol. The electrical signals are then decoded into data descriptive of the symbol.

The use of semiconductor devices as the light source in scanner system are especially desirable because of their small size, low cost and low power requirements. However, there are some drawbacks to the use of semiconductor devices in some applications.

First, some semiconductor lasers, especially those emitting light in the visible portion of the spectrum, have a relatively limited lifetime. The reflective facets which define the lasing cavity are relatively thin layers which degrade in reflectively over time. As a result, the effective output power of the laser also declines, which limits the operational effectiveness of the scanner.

As we will note later, since such degradation is proportional to the current applied to the diode. Of course, if the current applied is lowered, the device will have a longer lifetime.

In addition to gradual degradation, other degradation mechanisms are (1) catastrophic degradation, and (2) dark-line defect formation.

In catastrophic degradation, the laser mirror under high-power operation is permanently damaged by pits or grooves forming on the mirror.

The dark-line defect is a network of dislocations that can form during laser operation. Once started, it can grow expansively in a few hours, causing the threshold current density to increase.

Another disadvantage of the use of semiconductor lasers is that the rise in temperature associated with constant-on or high duty cycle operation will further reduce lifetime.

Still another disadvantage of semiconductor lasers presently available commercially is their relatively low visibility, compared, for example, to the visibility of the beam from a HeNe gas laser. Such low visibility is due to their high wavelength, about 680 nanometers.

Prior to the present invention there has not

been a satisfactory way to overcome the disadvantages of using a visible semiconductor laser in a scanning system for reading bar code symbols.

SUMMARY OF THE INVENTION

1. Objects Of The Invention

It is an object of the invention to provide a method and a device for reading coded indicia such as bar code symbols which is operable in both a low power mode and a high power mode in order to prolong the operational lifetime of the semiconductor light source.

It is another object of the invention to provide a method and a device for reading coded indicia which simultaneously adjusts the scanning angle of the emitted light and the power level of the emitted light.

It is yet another object of the invention to provide a device for reading coded indicia that includes a processing circuit that determines whether the reflected light of variable intensity represents a spatial variation that could be indicative of a predetermined indicia pattern.

2. Features Of The Invention

Briefly, and in general terms, the present invention provides a method and an apparatus for detecting indicia having portions of different light reflectivity such as bar code symbols. The invention includes a light source for emitting a light beam; and an optical component disposed in the path of the beam for optically modifying and directing the light beam along an optical path toward a target located in the vicinity of a reference plane lying generally normal to the optical path so as to scan spatially adjacent portions of the reference plane. The invention further includes a sensor having a field of view operative for detecting at least a portion of light of variable intensity reflected off the target, and for generating and electrical signal indicative of the detected light intensity. The electrical signal from the sensor is processed to produce a test signal to determine whether the reflected light of variable intensity represents a spatial variation of different light reflectivity that could be indicative of the presence of a predetermined indicia pattern, and for generating an enabling signal if the test signal exceeds a predetermined reference signal. The light beam is then modified in response to the enabling signal.

In another embodiment, the present invention provides a m thod and an apparatus for reading coded indicia on th surface of a target including a light source for illuminating the target, a detector for receiving at least a portion of the light reflected from th target, a decoder for decoding the reflected intensiti s of light into representations of th coded indicia, and a controller for operating th light source in a low power first mode and a high power second mode.

The novel features which are considered as characteristic of the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, best will be understood from the following description of specific embodiments when read in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWING

Figure 1 shows a highly simplified block diagram of a first embodiment of an apparatus for reading coded indicia such as bar code symbols according to the present invention;

Figure 2 shows a highly simplified block diagram of a second embodiment of a apparatus for reading coded indicia such as bar code symbols according to the present invention;

Figure 3a is a highly simplified schematic representation of the operation of the apparatus of the present invention during a first stage of operation in which coded indicia are not present in the scanning pattern of the emitted light;

Figure 3b is a highly simplified schematic representation of the operation of the apparatus of present invention during a second stage of operation in which a portion of a coded indicia are present in the scanning pattern of the emitted light;

Figure 3c is a highly simplified schematic representation of the operation of the apparatus of the present invention during a third stage of operation in which the entire coded indicia is present in the scanning pattern of the emitted light;

Figure 3d is a highly simplified schematic representation of the operation of the apparatus of the present invention during a fourth stage of operation after the indicia has been read and in which the entire coded indicia is still present in the scanning pattern of the emitted light;

Figure 4 is a schematic diagram of a detector circuit used in the apparatus according to the present invention;

Figure 5 is a graph of the power output of a semiconductor device used at the light source in the apparatus according to the present invention;

Figure 6a is a highly simplified, enlarged

view of a pattern of bars and spaces such as may be present in a typical symbol.

Figur 6b is a highly simplified graph of the voltage at an internal nod of th detection circuit corresponding to scanning the bar code symbol illustrated in Fig. 6a; and

Figure 6c is a graph of the enabling signal as a function of time corresponding to scanning of the symbol in Figure 6a from left to right.

In the several Figures, like reference numerals identify like parts.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The invention generally relates to scanner systems based upon semiconductor light sources for reading indicia of different light reflectivity such as bar code symbols. More particularly, the invention provides a scanner system in which adjustment of the intensity or spatial coverage of the beam is automatically made to effect appropriate detection, sweeping and/or scanning of symbols to be read. The invention further provides a method for operating a scanner system by providing a signal to the current drive of the light source and the scan controller in response to detection of indicia which represents or may represent a portion of a desired target, such as a bar code symbol. Referring generally to Figure 1 and 2, there are shown highly simplified block diagrams of embodiments of an apparatus for reading coded indicia, such as bar code symbols, according to the present invention. More particularly, reference numeral 10 generally identifies a preferably hand-held, fully portable scanning system for detecting, scanning, reading and/or analyzing bar code symbols. Typical symbol bar codes in current use are the Universal Product Code (UPC), EAN, Codabar and Code 39.

In the preferred embodiment of the present invention, the light source is a semiconductor laser. As we have noted previously, there are a number of drawbacks to operating a semiconductor laser scanner at full power over long periods of time, or under high duty cycle operation. First,some visible semiconductor lasers have a relatively limited lifetime. The reflective facets which define the lasing cavity are relatively thin layers which degrade in reflectively over time. As a result, the effective output power of the laser also declines, which limits the operational effectiveness of the scanner. However, such degradation increases as the current is applied to the diode; indeed, if the current applied is below the threshold current, the device will not lase at all. Under such conditions, the device will merely emit light by a process of spontaneous emission. Under conditions of low power, but abov threshold, the operational lifetime of th device may be extended over ten times, compared to that of a semiconductor laser operating at full pow r, e.g. up to 70,000 hours, or about 8 years, assuming constant-on conditions. Sinc scanners ar not typically operated in constant-on conditions, but in fact over much more limited conditions, in actual practice the increase in operational lifetime is considerable.

The second drawback is that, although most semiconductor laser diodes used in scanners today emit light at 780 nm, there is significant interest in lasers at a relatively shorter wavelength (i.e. 680 nm), which under certain conditions are visible to human eye. The sensitivity of the human eye to such wavelengths is relatively poor. As a result, the use of such light sources present the drawback that over large scan angles (e.g. more than about 15 degrees) the amount of light reflected from the target at the typical operational distance may not be visible to the eye of the user. Thus, the user cannot visually verify that the scanning is taking place over the symbol. Although various techniques may be utilized to overcome such limitation, including the use of an aiming light such as described in U.S. Patent Application Serial No. 706,502, such techniques detract from the simplicity of design and use which is desirable, especially in hand-held scanning devices.

The present invention also relates to scanning systems incorporating techniques for automatically initiating and terminating scanning of the target. One feature of some scanner systems is the use of a manually operated trigger to initiate scanning of the target, such as described in U.S. Patent No. 4,387,297. Although for many applications the use of a trigger is an important feature, there are some applications in which it may be desirable to use alternate activation techniques to initiating scanning.

The present invention provides a method and apparatus for operating a semiconductor laser in a scanning system which eliminates the need for a trigger to initiate scanning and also minimizes the operational time of the laser at high power. The present invention also provides a technique for adjusting the spatial coverage or sweep of the beam in order to maximize the reflected intensity visible to the user while also effecting a sufficient sweep to fully read.

Figure 1 shows a highly simplified block diagram of a first embodiment of an apparatus for reading coded indicia such as barcode symbols according to the present invention. The arrangement 10 may be implemented in a hand-held unit, mounted on a moveable stand, or incorporated in a fixed assembly such as a table-top or other equip-

ment. The arrangement includes a light source 11 for illuminating a target with a light beam. The light source 11 may be any sourc of intense light suitably selected for maximizing the reflectivity from th target, and may be a gas or semiconductor laser.

The arrangement 10 also includes a driver 12 connected to light sourc 11 for adjusting the intensity of the emitted light beam in accordance with a control signal from a first control unit 14.

The driver 12 is usually a current driver since in the preferred embodiment the light source is a semiconductor laser and one may adjust the light output of such a laser by increasing the forward current through the p-n junction of the laser. In the case the light source is not a laser, a suitable driver 12 is provided which is adapted to the emission characteristics of the light source 11 so as to vary the intensity of the output.

A scanning mechanism 13 is also provided which is operatively associated with the light source 11 for directing the light beam along a path to the target. The present invention is operable in a variety of different modes and in different arrangements to direct the light beam at the target. Since the coded indicia may be only a small portion of the field of view from the light source 11, it is often desirable to scan or sweep over a large spatial region to ensure that the sweep passes through the entire coded indicia. Thus, it may be desirable to scan in a pattern over a two dimensional region, such as described in U.S. Patent Application No. 138, 563 of the present assignee.

It is also desirable to employ a cyclically repeating scanning mechanism 13 to ensure that the indicia are read not just once during a single scan but are read a plurality of times during repeated scans, thereby increasing the reliability of the reading process and minimizing the possibility of error. Scanning mechanisms based upon optical, electronic, or mechanical techniques, either alone or in combination, are within the scope of the present invention, and such techniques are not necessarily limited to seanning or sweeping a light beam using a mirror such as in the arrangements described in the prior art patents noted above.

The arrangement 10 also includes a photodetector 15 for detecting the light reflected from the symbol and generating an electrical analog signal indicative of the detected variable light intensity. Since the symbol is swept with the light beam, the reflected light has a variable intensity as a function of time, corresponding to the reflections from the bars and spaces of the symbol. The output from the photodetector 15 is applied to amplifier (and digitizer) 16 which has an appropriate gain parameter which is preferably determined according to the working distance to the target. A detector circuit 17 is provided that functions to detect a certain pattern that represents a portion of a bar code symbol and is connected t the amplifier and digitizer 16.

An example of such a detector circuit 17 will be discussed at a later point in connection with Figure 4. In one embodiment of the present invention, the gain characteristics of the amplifier may be adjusted depending upon level of the output of the photodetector 15 in addition to a control signal from the detector circuit 17.

More particularly, the present invention provides an amplifier 16 having an adjustable gain characteristic. The amplifier is connected to the sensor photodetector 15 and functions to convert the relatively weak electrical signal from the photodetector 15 into an amplified signal. The amplified signal is then digitized and applied to th detector circuit 17 for further processing according to the present invemtion. The detector circuit may also function to apply a feedback signal to the amplifier/digitizer 16 and thereby control the gain characteristic of the amplifier. In one embodiment of the present invention the detector circuit 17 generates an output signal which we designate as a "laser enable" signal. Such a signal signifies that a portion of a bar code symbol has been detected. The "laser enable" signal is applied to the first control unit 14 to modify the light output from the light source 11 and/or signal the scanning mechanism 13 to change the angle of scan. The "laser enable" signal may also be used to activate a decode circuit 18 which will function to decode the signal received from the photodetector 15. Once activated, the decode circuit 18 is operative to receive data directly from the amplifier/digitizer 16, bypassing the detector circuit 17. The data output 19 from the decoder 18 can then pass the decoded data outside of the laser scanner in order to be used in a point-of-sale system. The enable signal may also be used as a feedback signal to control the gain characteristic of the amplifier/digitizer 16.

Figure 2 shows a highly simplified block diagram of a second embodiment of an apparatus for reading bar code symbols. The light source 11, the current drive 12, the scanning mechanism 13, the photodetector 15, and the amplifier/digitizer 16 may be the same as that described in connection with Figure 1 and are identified by like reference numerals.

In the embodiment of Figure 2, the system architecture is slightly different in that a manual trigger 22 turns the light source 11 on, and a second control unit 20 is provided which is responsive to the output of the detector circuit 17 to generate the laser enable signal 21. The manual trigger 22 initiates a "spot" mode of operation as will be subsequently described. The laser enable

signal 21 is connected to both the current drive 12 and th scanning mechanism 13 t modify the light output from the light source 11. and/or signal th scanning mechanism 13 to change the angle of scan. Once th control unit 20 is activated by eith r the output of the detector circuit 17, it will function to transfer data generated by the photodetector 15 to a data output line or connector 23. As in the embodiment of Figure 1, the enable signal may also be used as a feedback signal to control the gain characteristic of the amplifier/digitizer 16. Turning next to Figure 3, there is shown a sequence of views as a target containing a symbol is scanned by a light source 11 to show the operation of the present invention in one embodiment.

As suggested from the highly simplified discussion in connection with Figure 3, a feature of the present invention is to provide a circuit which is capable of sampling the reflected light from only a portion of a target and performing a computation or analysis on the detected electrical signal to determine if the detected portion is indicative that a bar code symbol has been detected. The preferred embodiment of such a detector circuit 17 will be subsequently described.

One technique according to the present invention is to process the electrical signal to produce a test signal to determine if the reflected light of variable intensity represents a spatial variation of different light reflectivity that could be indicative of the presence of a predetermined indicia pattern such as a bar code symbol.

An enabling signal would then be generated if the test signal exceeds a predetermined reference signal. The light beam is then modified in response to the enabling signal in one or more respects as will be subsequently described.

Another technique according to the present invention is to process the electrical signal to produce a count of the number of transitions between portions of different light reflectivity during a predetermined time period. The count would be used to determine whether the reflected light of different light reflectivity is indicative of a presence of a predetermined indicia pattern such as a generic bar code symbol, a class of bar code symbols, or even a specific bar code symbol. An enabling signal would be generated if the count exceeds a predetermined minimum. Again, the light beam would be modified in response to the enabling signal.

Still another technique according to the present invention is to process the electrical signal to compute the ratio of the length of a indicia portion of low light reflectivity to one of high reflectivity to determine whether the reflected light of variable intensity represents a spatial variation of different light reflectivity that could be indicative of a presence of a predetermined indicia pattern and for g n rating an enabling signal if the ratio is less than a predetermined value. The light b am would b modified in response to the enabling signal.

Yet another technique according to the present invention is to process the lectrical signal to compare the signal from a first scan with the signal from a second subsequent scan to determine whether the reflected light of variable intensity over successive scans represents a substantially identical spatial variation of different light reflectivity that could be indicative of a presence of a predetermined indicia pattern. An enabling signal is generated if the comparison between a predetermined number of successive scans results in identical match. The light beam would be modified in response to the enabling signal.

Figure 3a is a highly simplified schematic representation of the operation of the apparatus of the present invention during a first stage of operation in which coded indicia are not present in the scanning pattern of the emitted light.

The operation of the present invention begins when a portion of a coded indicia is present in the scanning pattern, i.e. at the second stage shown in Figure 3b. As the scanner is moved to the location of the coded indicia, a portion of a coded indicia will be present in the scanning pattern of the emitted light from the light source 11. The detector circuit 17 is now operative to detect a portion of a symbol and will generate a laser enable signal, and shift operation of the apparatus into a third stage of operation.

Figure 3c is a highly simplified schematic representation of the operation of the apparatus of the present invention during a third stage of operation in which the entire coded indicia is present in the scanning pattern of the emitted light. The indicia will then be read, decoded, and data transferred, as will be subsequently described.

Figure 3d is a highly simplified schematic representation of the operation of the apparatus of the present invention during a fourth stage of operation after the indicia has been read and in which the entire coded indicia is still present in the scanning pattern of the emitted light. As shown in the Figure, the light beam has now narrowed so that only a portion of teh indicia are covered by the beam.

As suggested from the highly simplified discussion in connection with Figure 3, a feature of the present invention is to provide a circuit which is capable of sampling the reflected light from only a portion of a target and performing a computation or analysis to determine if the detected portion is indicative that a bar code symbol has been detected. According to the embodiment shown in Figure 3, th result of the computation or analysis

may b used to change the scanning angle or length of the scanning path betwe n th second and third stages, as well as between the third and fourth stages of operation.

In other embodiments, another parameter characteristic of the light beam may be modified, such as the intensity, the spot size at th referenc plane, or the rate of scanning.

Once the entire coded indicia has been decoded, it is no longer necessary to maintain the scanning angle 30 (and/or perhaps a high level of light intensity from the light source 11 as well) in third stage. Thus after a predetermined time-out period, the light beam of the apparatus will revert back to substantially the same configuration as the first stage, as shown in Figure 3d. In such a situation, the detector circuit 16 will be inhibited even though a portion of a symbol is being detected.

To summarize the operation of the scanner according to the present invention, one feature of the present invention is to provide a circuit which is capable of sampling the reflected light from only a portion of a target and performing a computation or analysis to determine if the detected portion is indicative that a bar code symbol has been detected. Once it has been determined that a bar code symbol has been detected, some characteristic of the light beam is modified in order to complete the scanning and decoding operation.

The particular characteristic of the light beam that should be modified depends upon the designing and application of the scanner, and the mode of operation of the scanner. Before turning to a more detailed description of the embodiments of the present invention, it would be worthwhile to discuss the design feature of a laser scanner that have some impact on the implementation of the present invention.

In the design of the laser scanner, there are various technical characteristics that can be considered some of which (such as the nature of the light beam) can be adjusted and modified using the principles of the present invention during the scanning process. The discussion of such characteristics hereunder is not intended to limit or circumscribe the scope of the present invention, but is meant to illustrate the possible application of the technical features of the present invention to both laser design factors and specific user considerations. Following a discussion of such technical characteristics, we will consider application-specific characteristics such as scanning modes.

The characteristics we shall discuss include: the brightness of the laser beam (i.e. the effective power output), regulatory requirements and standards, and technical performance characteristics (such as laser lifetime, cost of design, manufacturability, and similar characteristics).

Th brightness of the laser beam reflecting from th surface of th target is a critical parameter in the design of a laser scanner, particularly a hand-held laser scanner. Since such scanners ar aimed by the user by pointing the beam at th bar cod , it is important that the reflective beam from th laser b sufficiently perceptible to th us r under a wide variety of ambient light conditions to make aiming not only possible but easy to use. The brightness of the laser beam is a function of a number of different parameters, including the wavelength of the laser light (since the eye has varying sensitivities depending upon wavelength, and in particular the lower the wavelength in th red region the more sensitive the eye is to respond to the reflective beam), the size of the spot, the power, and the length of the path over which the beam is swept in a scanning mode.

Since the wavelength of the laser diode is relatively fixed, and the spot size is determined by resolution, the designer typically has only the two parameters of the power and scanning length to vary. The variation of either or both of such parameters may be utilized in a given application. The parameters may be changed at periodic intervals during operation, or may be triggered by the user. For example, in an operational mode the brightness is maximized only while the user is searching for the target and using the beam to aim the scanner - such mode may be called an "aim" mode.

Another technical characteristics pertaining to laser scanners are regulatory requirements and standards. Such regulatory standards are often concerned with the amount of power emitted by the laser over a period of time.

For example, the Center for Devices and Radiological Health (CDRH) categorizes laser devices into four classes, Class I through Class IV. A Class I laser emits a maximum of 0.39 microwatts radiant power for a time period of greater than 10,000 seconds. Such a device is very low power and offers very little danger to health or safety. Class IIa lasers emit a maximum of 3.9 microwatts radiant power over a time period of greater than 1,000 seconds. Class II devices require a simpl cautionary label bearing the words "CAUTION" and a starburst symbol, and an aperture label bearing the words "Avoid exposure - laser light is emitted from this aperture." The Class II warning logtype contains the word "Caution", the phrases "Laser light - do not stare into beam", "Class II laser product", a phrase describing the laser medium and output power, and the starburst symbol. Th present invention is also useful to insure compliance with regulatory standards concerning laser light emission. By emitting a high power beam over a relatively short period of time, the laser according to the present invention will lie within regulatory

constraints yet permit a bright enough spot to be generated on the reference plane so as to enable a user to perceive it and mak use of it f r aiming th laser scanner. Depending upon the particular constraints of the specific regulation, the power output, spot size, scanning angl , scan speed or other parameters of the laser scanner may be suitably chosen by the designer so as to optimize visibility of the beam to the user while still conforming to regulatory specifications for a particular class of laser.

The features of the present invention may also be utilized to operate the laser scanner in different scanning modes.

There are three possible scanning modes that we might consider for a hand-held laser scanner according to the present invention: (a) the normal triggered mode; (b) the triggered spot and scan mode; and (c) the object sensor mode.

In the normal triggered mode, the laser beam is normally off. A trigger is used in the normal triggered mode to initiate the rapid and repetitive scanning of the target symbol. For proper operation, it is necessary to distinguish between whether many scans have been performed for one object, or whether one scan has been performed for many objects. The capability of sensing each object to be scanned in its turn is critical for successful decoding.

As is known in prior art scanners (such as described in U.S. Patent No. 4,387,297) a trigger is operative for actuating the scanning means to repetitively sweep the barcode symbol a number of times each time the trigger is actuated. The trigger is preferably a manually-depressible switch mounted on the housing in the vicinity of the interconnection of the barrel and handle portions of the housing. The trigger switch is located on the handle portion such that the forefinger of the user's hand can be used to manually depress the switch. Each time the switch is depressed the scanning means sweeps the symbol many times, until a complete decoder or a time out is reached.

In the triggered mode, when the decode circuitry successfully decodes the symbol, the decode circuitry generates a successful decode signal and may actuate the indicator means located in the scanner. The indicator means comprises and auditory-type beeper and/or a light emitting diode. When the beeper sounds and/or when the diode lights up, then the user knows that the scanning for that particular symbol has been terminated.

In the triggered spot and scan mode, after the trigger is pulled, the beam comes on at a narrow angle. In such an operational mode, a very bright, short line about 1" in length is formed by the laser narrow scanning beam. Th bright small line is used by th user holding th laser scanner to manually aim and direct th beam to the location where the user actually sees the barcode is located. When an indicia pattern indicativ of a barcode symbol has been detected, the b am will widen thereby sweeping the entire symbol so that it can be decoded. Th beam may be dimly reflective or not visible to the user, but the decode will take place. It is desirable but not necessary that the system detect a barcode only when the bright line is on a symbol, not text or graphics.

In the object sensor mode, the scanner is trigger-less and the constantly on laser beam normally emits at a narrow angle and lower power. When an indicia pattern indicative of a barcode symbol has been detected, the beam will widen, the power will increase, and the beam will read the entire symbol. Any or all of the above operational modes may be utilized on a single laser scanner utilizing the bar code symbol detection techniques according to the present invention. Such operational modes may be chosen manually by the user (such as by setting a switch) or the laser scanner may be dedicated to operate in a specific operational mode. The different laser beam output or scanning parameters discussed.above - beam intensity, angle of scan, etc. - may either be manually selected by the user (such as by setting a switch) or may be automatically determined and dedicated in a particular type of scanner. The particular type of scanning parameter may also conceivably be automatically determined by an analysis of the detected bar code and a computer algorithm may determine the most appropriate subsequent scanning mode to be utilized in order to most effectively and appropriately detect the entire bar code symbol. Such alternative embodiments are all within the range and scope of present invention.

Turning next to Figure 4, there is shown a schematic diagram of an embodiment of a preferred detector circuit 17 according to the present invention. The signal from the amplifier/digitizer 16 is applied to the input of an invertor 31, the output of which is applied to a diode 32. An RC circuit is formed by first resistor R1 and capacitor (C) 34 with the resistor R1 being connected in series between the output of the diode 32 and a first input 35 of an open collector output comparator 37. The capacitor (C) 34 is connected between the first input 35 and ground potential, and a second resistor R2 is connected between first input 35 and ground potential. The resistance value of resistor R1 is preferably much less than that of resistor R2.

The second input 38 of the comparator is connected to the node of a voltage divider formed by resistors R4 and R5 which are connected in series between potential V and ground. The output 41 of the comparator 37 is connected to the "laser enabl " signal line, as well as a feedback through a

resistor R3. Th feedback from the output of th comparator 37 provides a hysteresis effect to the comparison operation since the other terminal of th resistor R3 is connected to the second input 38 of the comparator 37. The operation of th d tector circuit 17 can be described as follows: when the digitizer outputs a bar, the capacitor charges up with a time constant of approximately R1C since R2 is much greater than R1. When the digitizer outputs a space, the capacitor discharges through R2 since the diode 32 prevents the discharging through R1. The time constant R2C is much greater than the time constant R1C so that more space time is required to cancel the effect of a bar. After several bars and spaces of typical density, a voltage is developed on the capacitor 34 which exceeds the threshold which has been set with the use of the comparator 37. At this time, a "trigger" or laser enable signal is output from the comparator 37 to indicate the presence of a bar code.

The open collector output of the comparator 37 is driven low at this point which lowers the threshold of the comparator so that minor voltage changes on the capacitor 34 due to the following bars and spaces, and quiet zone, will not disable the trigger signal.

The circuit as described would also trigger if a long black bar were to be scanned. However, in the preferred embodiment, the digitizer includes a circuit which discriminates against reading a long black bar, i.e. the digitizer functions as a high pass filter. One such digitizer circuit would utilize a time-out so that if a long black bar was scanned, only a short pulse would be generated. When such a short pulse signal is applied to the detector circuit 16, the threshold will not be exceeded and a "trigger" signal will not be output.

The trigger signal will only be released after a relatively long time during which there are no bars digitized. When the scanner is moved away from a symbol, the capacitor will discharge through R2C and the trigger signal will be released which will indicate to the decoding logic or the detector circuit that the same symbol is no longer being scanned.

The bar code sensing circuit depicted in Figure 4 is one of the key features of the present invention since it is sensitive to a specific pattern of images. The circuitry is responsive to a pattern of high and low reflected light signals to charge and discharge the capacitor 34, with the net charge being utilized to generate a trigger signal after some threshold has been reached.

Figure 6a is a highly simplified enlarged view of a pattern of bars and spaces such as may be present in a typical symbol. Figure 6b is a graph of the voltage on the line 35 as a function of time corresponding to scanning of the symbol in Figure 6a from left to right. More particularly, it is seen that as a bar is trav rsed, the voltag increases somewhat lin arly as seen during the time period designated by th reference charact r a. As a space is traversed, as during th time p riod designed by th reference character b, there is no charge applied through R1 and th existing charge on the capacitor C is slowly discharged through the resistor R2. As the next bar is encountered during time period c, a voltage is again applied to charge the capacitor through resistor R1.

As the next space is encountered during the scan, during the period d, there is again no charge applied through the resistor R1 and the existing charge on the capacitor C is again slowly discharged throughout resistor R2. As the next bar is encountered, wide bar 53 during the scan, during the time period e, a voltage is again applied to charge the capacitor C through resistor R1. As seen in Figure 6b, the total voltage on the line 35 surpasses the threshold voltage Vt during the time period e. As further shown in Figure 6b, at the tim the voltage surpasses the threshold voltage Vt, a trigger enable signal is activated, which is shown in Figure 6c, by the trigger signal going from a high state to a low state. The voltage on the line 35 continues to increase during the time period e as the bar 53 is scanned. During the time period f in which a space is being scanned, no charge is applied through the resistor R1 and the existing charge on the capacitor C is slowly discharged through the resistor R2. As the next bar 54 is encountered during the time period g, a voltage is again applied to charge the capacitor through resistor R1.

In the embodiment of the present invention, a circuit may be provided to pulse the laser on for long enough time to complete one scan over th field. The circuit would then turn the laser off for some period of time before repeating the cycle. At the end of the period of time during which the laser is on, the laser enable output of the circuit in Figure 4 is latched and the output of the latch is used in the system as the laser enable output. Since the latch output will not change until the end of the next laser-on period, the discharging of the capacitor C during the laser-off time will not hav any effect on the latch output. The parameters R1, R2 and C should be appropriately chosen so th voltage on the capacitor C reaches the steady state condition within one scan time.

During period g, the voltage on C reaches nearly a steady state value which is close to V, i.e. close to the maximum of V(1-exp(-t/R1C)). The voltage will stay near the level V until the bar cod no longer appears in the field of view of th photodetector 15. At the time the bar code disappears, the capacitor discharges, as represented by period h in Figure 4.

Th laser enable signal output applied to the control until 14 or 20 may b utilized to detect specific spatial variation patterns through the us of appropriate hardware or software provided in the control unit 14 or 20. For exampl , through an appropriate selection of param ters for the detection circuit 17, the control unit 14 or 20 may be provided with appropriate logic to count of the number of transitions between portions of different light reflectivity during a predetermined time period. The count would be used to determine whether the reflected light of different light reflectivity is indicative of a presence of a predetermined indicia pattern such as a generic bar code symbol.

The control unit 14 or 20 may also compute the ratio of the length of a indicia portion of low light reflectivity to that of an indicia portion of high light reflectivity to determine whether the reflected light of variable intensity represents a spatial variation of different light reflectivity that could be indicative of a presence of a predetermined indicia pattern and for generating an enabling signal if the ratio is less that a predetermined value.

Yet another application of the control unit 14 or 20 may be to compare the signal from a first scan with the signal from a second subsequent scan to determine whether the reflected light of variable intensity over successive scans represents a substantially identical spatial variation of different light reflectivity that could be indicative of a presence of a predetermined indicia pattern. An enabling signal is generated if the comparison between a predetermined number of successive scans results in identical match.

Turning next to Figure 5, there is shown a graph of the source output of a semiconductor device used as the light source as a function of the driving current Id. In particular, there is shown a transition point It which represents the laser threshold current point. As the laser diode current is increased, the power output due to spontaneous emission increases relatively slowly. After the threshold current its point is crossed, the output increases sharply as laser oscillation begins.

There are two operating current points according to the present invention, I1 and I2, both of which are preferably in the region of laser oscillation. It is also possible to operate at a current in which I1 is in the region of spontaneous emission.

The operation of the present invention in the object sensing mode may be explained as follows. (Operation in other modes is similar and need not be described in detail here). The light source 11 is operated in a low power first mode associated with driving current I1, and the scanning mechanism 13 is operative at a relatively narrow scanning angle during the first or "detect" mode of operation, such as depicted in Figure 3a. Although the power is low in the first mod , th beam image produc d by the narrow scanning angle makes th light reflecting from the target appear as a short, bright line visibl to the user, and thus the light may be used as an aiming beam to enable the user to point at the symbol t be decoded. When the detector circuit 16 determines that a portion of a symbol is in the field of view of the scanning pattern, such as in Figure 3b, the apparatus switches over to a second mode of operation. In the second mode, the light source 11 is operated in high power associated with driving current I2, and the scanning angle is increased to that depicted in Figure 3c. Because of the relatively large scanning angles, it is quite likely that the image of the beam on the target will not be visible to the user.

However, since the unit will be operated for only a short period of time in the second mode, the fact that the image of the beam on the target is not visible is not a major drawback.

After the decoding has taken place, the unit will shift back to the first operating mode, as shown in Figure 3d. The dectector circuit will continue to indicate that the symbol is being scanned. When in object sensing mode, in order to prevent multiple reads of the same symbol, the control circuit contains logic that requires the laser enable signal to go away for a time before starting up the cycle again, and come on again to the wide scan angle. The image of the beam will once again be visible to the user. If no bar code is read during a short time period (e.g. 1 to 10 seconds) it is assumed that the device did not focus on a valid bar code symbol, and the unit will automatically shift back to the first stage of operation so that the user may aim the scanner once again at the bar code symbol.

One embodiment of the present invention allows a scanner to distinguish between a bar code symbol and a regular pattern of light and dark areas such as that formed by printed characters.

Such a feature is particularly important since in most applications the article being scanned has a considerable amount of text in the form of printed characters disposed over the entire surface, in addition to a single bar code symbol. One of the key advantages of the present invention is to allow the scanner to disregard all of the text and be enabled only by the actual bar code symbol.

Although the present invention has been described with respect to linear or single line bar codes, it is not limited to such embodiments, but may also be applicable to stacked or two dimensional bar codes such as Code 49 and similar symbologies. It is conceivable that the scanning method of the present invention may also find application for use with various machine vision or optical character recognition applications in which

information is d rived from other types of indicia such as characters or from the surface characteristics of th artic b ing scanned.

In all of th various embodiments, th elements of th scanner may b assembled into a very compact package that allows the scanner to b fabricated as a singl printed circuit board or integral module. Such a module can interchangeably be used as the laser scanning element for a variety of different types of data acquisition systems. For example, the module may be alternately used in a hand-held scanner, a table top scanner attached to a flexible arm or mounting extending over the surface of the table or attached to the underside of the table top, or mounted as a subcomponent or subassembly of a more sophisticated data acquisition system.

The module would advantageously comprise a laser/optics subassembly mounted on a support, a scanning element such as a rotating or reciprocating mirror, and a photodetector component. Control or data lines associated with such components may be connected to an electrical connector mounted on the edge or external surface of the module to enable the module to be electrically connected to a mating connector associated with other elements of data acquisition system.

An individual module may have specific scanning characteristics associated with it, e.g. operability at a certain working distance, or operability with a certain density of symbols. The scanning characteristics may also be defined through the manual setting of control switches associated with the module. The user may also adapt the data acquisition system to scan different types of articles or the system may be adapted for different applications by interchanging modules on the data acquisition system through the use of the simple electrical connector.

The scanning module described above may also be implement within a self-contained data acquisition system including one or more such components as keyboard, display, data storage, application software, and data bases. Such a system may also include a communications interface to permit the data acquisition system to communicate with other components of a local area network or with the telephone exchange network, either through a modem or an ISDN interface, or by low power radio broadcast from the portable terminal to a stationary receiver.

It will be understood that each of the features described above, or two or more together, may find a useful application in other types of scanners and bar code readers differing from the types described above.

While the invention has been illustrated and described as embodied in scanners with adjustable light output and/or scanning angles, it is not intended to b limited to th details shown, since various modifications and structural changes may be mad without departing in any way from the spirit of the present invention.

Without further analysis, the foregoing will so fully reveal th gist of th present invention that others can readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly constitute essential characteristics of the generic of specific aspects of this invention and, therefore, such adaptions should and are intended to be comprehended within the meaning and range of equivalence of the following claims.

Claims

1. Apparatus for detecting indicia having portions of different light reflectivity such as bar code symbols comprising:

(a) a light source for emitting a light beam;

(b) an optical component disposed in the path of said beam for optically modifying and directing the light beam along an optical path toward a target located in the vicinity of a reference plan lying generally normal to the optical path so as to scan spatially adjacent portions of said reference plane;

(c) sensor means having a field of view and operative for detecting at least a portion of light of variable intensity reflected off the target, and for generating and electrical signal indicative of the detected light intensity;

(d) means for processing said electrical signal to produce a test signal to determine whether the reflected light of variable intensity represents a spatial variation of different light reflectivity that could be indicative of the presence of a predetermined indicia pattern;

(e) means for generating an enabling signal if the test signal exceeds a predetermined reference signal; and

(f) means for modifying the light beam in response to said enabling signal.

2. Apparatus as defined in claim 1, wherein said means for modifying the light beam functions to change the intensity of the light beam.

3. Apparatus as defined in claim 1, wherein said means for modifying the light beam functions to change the spot size of the light beam at the reference plane.

4. Apparatus as defined in claim 1, wherein said means for modifying the light beam functions to change the optical path of said light beam so as to define a different scanning path on said reference plane.

5. Apparatus as defined in claim 1, wherein

said means for modifying functions to change the rate of scanning of said light beam.

6. Apparatus as defined in claim 1, further comprising amplifier means having an adjustable gain characteristic, said amplifier m ans being connected to said sensor m ans and functioning to convert the electrical signal from said sensor means into an amplified signal; said means for processing further functioning to control the gain characteristic of said amplifier means in response to said enabling signal.

7. Apparatus as defined in claim 1, wherein said light source is a semiconductor device for emitting a light beam having an intensity which is related to the driving current applied to said semiconductor device.

8. Apparatus as defined in claim 7, further comprising means for controlling the driving current applied to said semiconductor device.

9. Apparatus as defined in claim 8, wherein said means for controlling the driving current functions to operate said semiconductor device in a low power first mode and a high power second mode, said means for controlling being responsive to said enabling signal to change from said first mode to said second mode.

10. Apparatus as defined in claim 9, further comprising timing means connected to said means for controlling the driving current, said timing means functioning to operate said semiconductor device in the high power second mode for only a predetermined time duration.

11. Apparatus as defined in claim 6, wherein said amplifier means further comprises a digitizer for converting the electrical signal from said sensor means into a digital signal.

12. Apparatus for detecting indicia having portions of different light reflectivity such as bar code symbols comprising:

(a) a light source for emitting a light beam;

(b) an optical component disposed in the path of said beam for optically modifying and directing the light beam along an optical path toward a target located in the vicinity of a reference plane lying generally normal to the optical path so as to scan spatially adjacent portions of said reference plane;

(c) sensor means having a field of view and operative for detecting at least a portion of light of variable intensity reflected off the target, and for generating and electrical signal indicative of the detected light intensity;

(d) means for processing including an RC circuit which is charged when a portion of an indicia having a low light reflectivity and short duration is detected by a sensor means and is discharged when a portion of an indicia having high reflectivity is detected by said sensor means, and for generating a test signal that represents the cumulative charg s on said RC circuit;

(e) means for generating an enabling signal if the test signal exceeds a predetermined reference signal; and

(f) means for modifying the light beam in response to said enabling signal.

13. Apparatus for detecting indicia having portions of different light reflectivity such as bar code symbols comprising:

(a) a light source for emitting a light beam;

(b) an optical component disposed in the path of said beam for optically modifying and directing the light beam along an optical path toward a target located in the vicinity of a reference plane lying generally normal to the optical path so as to scan spatially adjacent portions of said reference plane;

(c) sensor means having a field of view and operative for detecting at least a portion of light of variable intensity reflected off the target, and for generating an electrical signal indicative of the detected light intensity;

(d) means for processing said electrical signal to produce a count of the number of transitions between portions of different light reflectivity during a predetermined time period to determine whether the reflected light of variable intensity represents a spatial variation of different light reflectivity that could be indicative of a presence of a predetermined indicia pattern;

(e) means for generating an enabling signal if the count exceeds a predetermined minimum; and

(f) means for modifying the light beam in response to said enabling signal.

14. Apparatus as defined in claim 13, wherein said means for modifying the light beam functions to change the intensity of the light beam.

15. Apparatus as defined in claim 13, wherein said means for modifying the light beam functions to change the spot size of the light beam at the reference plane.

16. Apparatus as defined in claim 13, wherein said means for modifying the light beam functions to change the optical path of said light beam so as to define a different scanning path on said reference plane.

17. Apparatus as defined in claim 13, further comprising amplifier means having an adjustable gain characteristic, said amplifier means being connected to said sensor means and functioning to convert the electrical signal from said sensor means into an amplified signal, said means for processing further functioning to control the gain characteristic of said amplifier means in response to said amplified signal.

18. Apparatus as defined in claim 13, wherein

said light sourc is a semiconductor devic for emitting a light b am having an int nsity which is r lated to the driving current applied to said semiconductor device.

19. Apparatus as defined in claim 18, further comprising means for controlling the driving current applied to said semiconductor device.

20. Apparatus for detecting indicia having portions of different light reflectivity such as bar code symbols comprising:

(a) a light source for emitting a light beam;

(b) an optical component disposed in the path of said beam for optically modifying and directing the light beam along an optical path toward a target located in the vicinity of a reference plane lying generally normal to the optical path so as to scan spatially adjacent portions of said reference plane;

(c) sensor means having a field of view and operative for detecting at least a portion of light of variable intensity reflected off the target, and for generating an electrical signal indicative of the detected light intensity;

(d) means for processing said electrical signal to compute the ratio of the length of a indicia portion of low light reflectivity to the length of an indicia portion of high light reflectivity to determine whether the reflected light of variable intensity represents a spatial variation of different light reflectivity that could be indicative of a presence of a predetermined indicia pattern;

(e) means for generating an enabling signal if the ratio is less than a predetermined value; and

(f) means for modifying the light beam in response to said enabling signal.

21. Apparatus as defined in claim 20, wherein said means for modifying the light beam functions to change the intensity of the light beam.

22. Apparatus as defined in claim 20, wherein said means for modifying the light beam functions to change the spot size of the light beam at the reference plane.

23. Apparatus as defined in claim 20, wherein said means for modifying functions to change the optical path of said light beam so as to define a different scanning path on said reference plane.

24. Apparatus as defined in claim 20, further comprising amplifier means having an adjustable gain characteristic, said amplifier means being connected to said sensor means and functioning to convert the electrical signal from said sensor means into an amplified signal, said means for processing further functioning to control the gain characteristic of said amplifier means in response to said amplified signal.

25. Apparatus as defined in claim 20, wherein said light source is a semiconductor device for emitting a light beam having an intensity which is related to the driving current applied to said semiconductor d vice; and further comprising means for controlling th driving current applied to said semiconductor device.

26. Apparatus for detecting indicia having portions of differ nt light reflectivity such as bar code symbols comprising:

(a) a light source for emitting a light beam;

(b) an optical component disposed in the path of said beam for optically modifying and directing the light beam along an optical path toward a target located in the vicinity of a reference plane lying generally normal to the optical path so as to scan spatially adjacent portions of said reference plane;

(c) sensor means having a field of view and operative for detecting at least a portion of light of variable intensity reflected off the target, and for generating an electrical signal indicative of the detected light intensity;

(d) means for processing said electrical signal to compare the signal from a first scan with th signal from a second subsequent scan to determine whether the reflected light of variable intensity over successive scans represents a substantially identical spatial variation of different light reflectivity that could be indicative of a presence of a predetermined indicia pattern,

(e) means for generating an enabling signal if the comparison between a predetermined number of successive scans result in identical match of spatial variation of light reflectivity; and

(f) means for modifying the light beam in response to said enabling signal.

27. Apparatus as defined in claim 26, wherein said means for modifying the light beam functions to change the intensity of the light beam.

28. Apparatus as defined in claim 26, wherein said means for modifying the light beam functions to change the spot size of the light beam at the reference plane.

29. Apparatus as defined in claim 26, wherein said means for modifying functions to change the optical path of said light beam so as to define a different scanning path on said reference plane.

30. Apparatus as defined in claim 27, further comprising amplifier means having an adjustabl gain characteristic, said amplifier means being connected to said sensor means and functioning to convert the electrical signal from said sensor means into an amplified signal, said means for processing further functioning to control the gain characteristic of said amplifier means in response to said amplified signal.

31. Apparatus as defined in claim 27, wherein said light source is a semiconductor device for emitting a light beam having an intensity which is related to the driving current applied to said semi-

conductor device, and further comprising means for controlling the driving current applied to said semiconductor device.

32. A method for detecting indicia having portions of differ nt light ref lctivity such as bar code symbols comprising the steps f:

(a) providing a light source for emitting a light beam;

(b) optically modifying and directing the light beam along an optical path toward a target located in the vicinity of a reference plane lying generally normal to the optical path so as to scan spatially adjacent portions of said reference plane;

(c) detecting at least a portion of light of variable intensity reflected off the target and generating an electrical signal indicative of the detected light intensity;

(d) processing said electrical signal to produce a test signal to determine whether the reflected light of variable intensity represents a spatial variation of different light reflectivity that could be indicative of the presence of a predetermined indicia pattern;

(e) generating an enabling signal if the test signal exceeds a predetermined reference signal; and

(f) modifying the light beam in response to said enabling signal.

33. A method for detecting indicia having portion of different light reflectivity such as bar code symbols comprising the steps of:

(a) providing a light source for emitting a light beam;

(b) optically modifying and directing the light beam along an optical path toward a target located in the vicinity of a reference plane lying generally normal to the optical path so as to scan spatially adjacent portions of said reference plane;

(c) detecting at least a portion of light of variable intensity reflected off the target, and for generating an electrical signal indicative of the detected light intensity;

(d) processing said electrical signal to produce a count of the number of transitions between portions of different light reflectivity during a predetermined time period to determine whether the reflected light of variable intensity represents a spatial variation of different light reflectivity that could be indicative of a presence of a predetermined indicia pattern;

(e) generating an enabling signal if the count exceeds a predetermined minimum; and

(f) modifying the light beam in response to said enabling signal.

34. A method for detecting indicia having portions of different light reflectivity such as bar code symbols comprising the steps of:

(a) providing a light source for emitting a light beam;

(b) optically modifying and directing the light beam along an optical path toward a target located in th vicinity of a reference plane lying generally normal t the optical path s as t scan spatially adjacent portions of said r ference plane;

(c) detecting at least a portion of light of variable intensity reflected off the target, and for generating an electrical signal indicative of the detected light intensity;

(d) processing said electrical signal to compute the ratio of the length of a indicia portion of low light reflectivity to the length of an indicia portion of high light reflectivity to determine whether the reflected light of variable intensity represents a spatial variation of different light reflectivity that could be indicative of a presence of a predetermined indicia pattern;

(e) generating an enabling signal if the ratio is less than a predetermined value; and

(f) modifying the light beam in response to said enabling signal.

35. A method for detecting indicia having portions of different light reflectivity such as bar code symbols comprising:

(a) providing a light source for emitting a light beam;

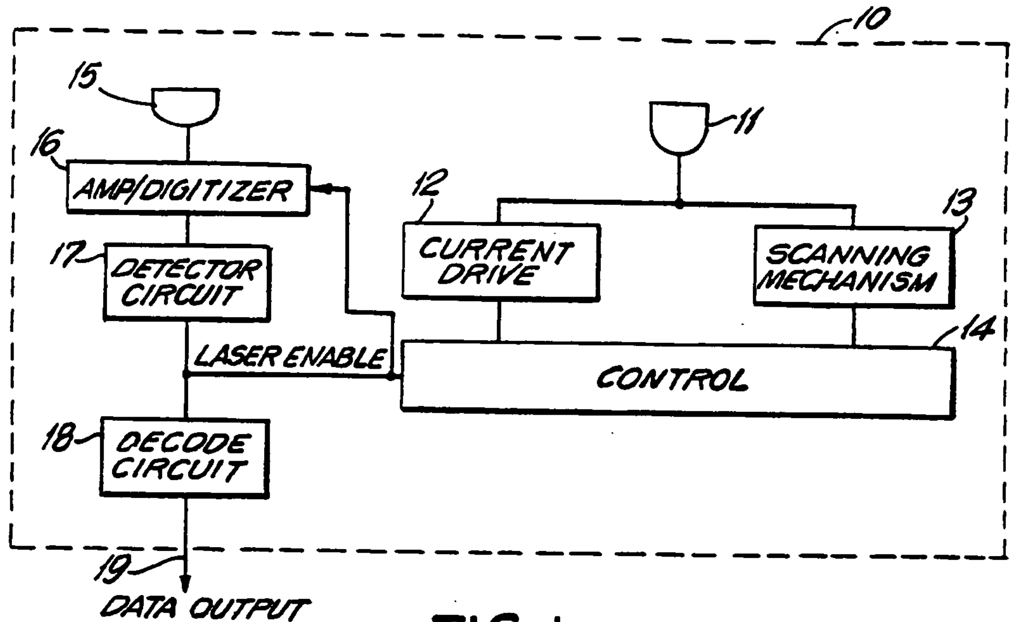
(b) optically modifying and directing the light beam along an optical path toward a target located in the vicinity of a reference plane lying generally normal to the optical path so as to scan spatially adjacent portions of said reference plane;

(c) detecting at least a portion of light of variable intensity reflected off the target, and for generating an electrical signal indicative of the detected light intensity;

(d) processing said electrical signal to compare the signal from a first scan with the signal from a second subsequent scan to determine whether the reflected light of variable intensity over successive scans represents a substantially identical spatial variation of different light reflectivity that could be indicative of a presence of predetermined indicia pattern;

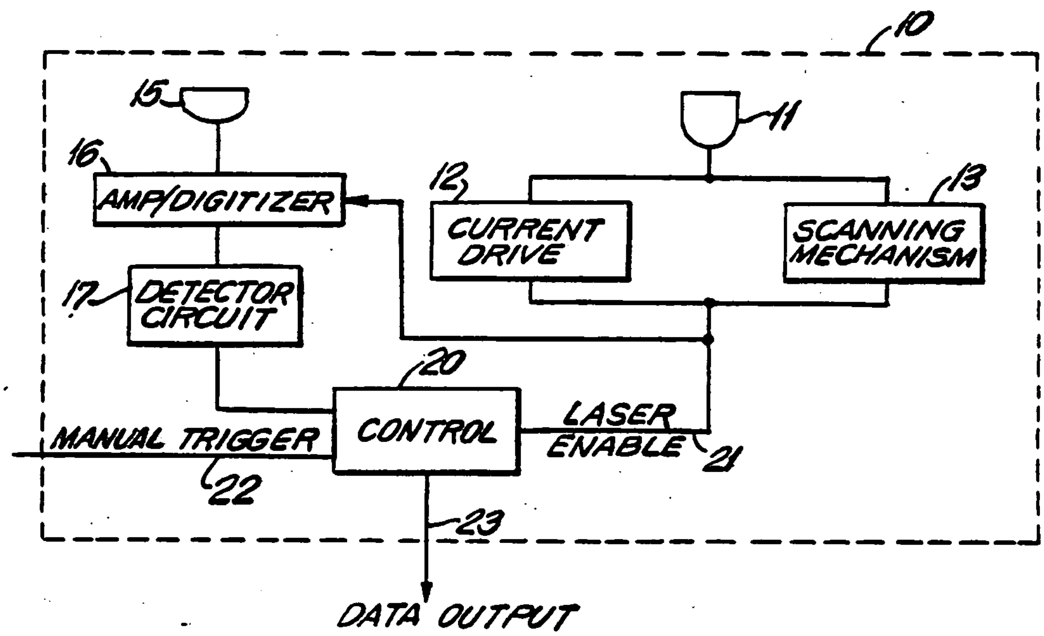
(e) generating an enabling signal if the comparison between a predetermined number of successive scans result in identical match of spatial variation of light reflectivity; and

(f) modifying the light beam in response to said enabling signal.



10
15
11
16
AMP/DIGITIZER
12
13
17
DETECTOR CIRCUIT
CURRENT DRIVE
SCANNING MECHANISM
14
LASER ENABLE
CONTROL
18
DECODE CIRCUIT
19
DATA OUTPUT

FIG. 1



10
15
11
16
AMP/DIGITIZER
12
13
CURRENT DRIVE
SCANNING MECHANISM
17
DETECTOR CIRCUIT
20
MANUAL TRIGGER
CONTROL
LASER ENABLE
22
21
23
DATA OUTPUT

FIG. 2

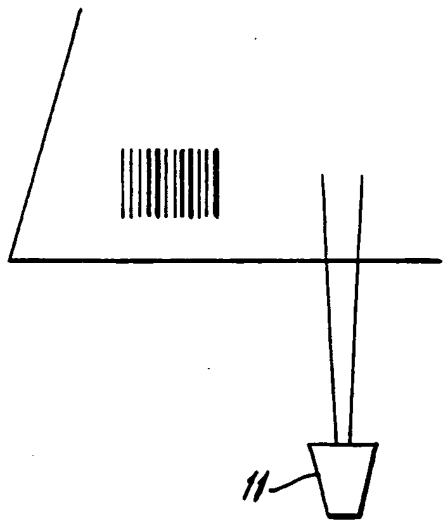


FIG.3(a)

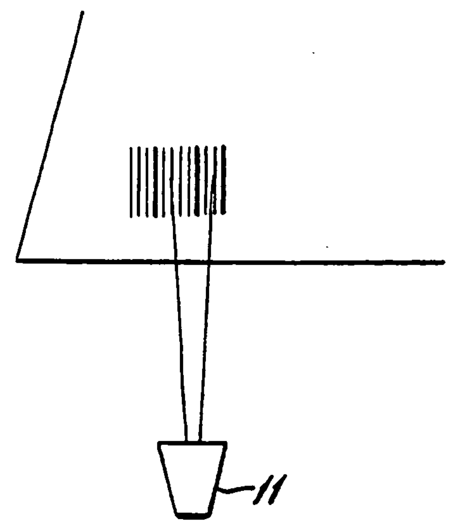


FIG.3(b)

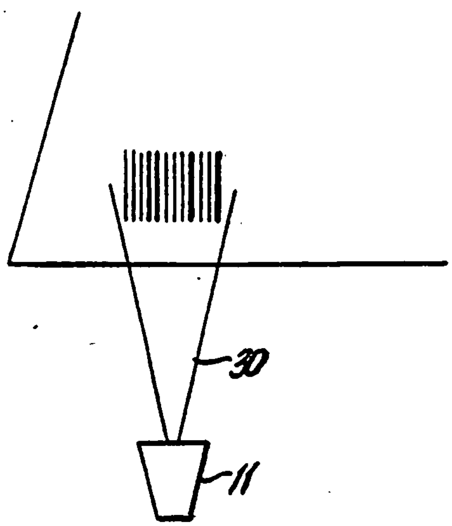


FIG.3(c)

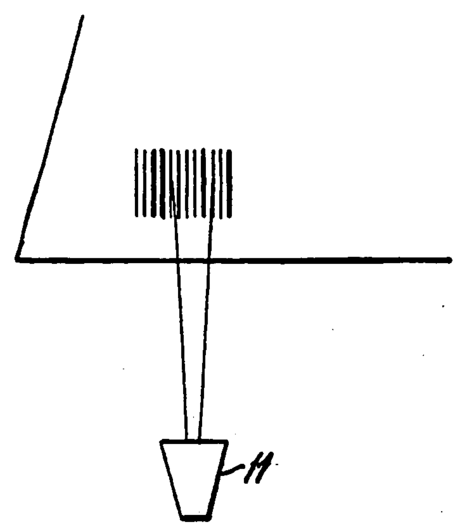


FIG.3(d)

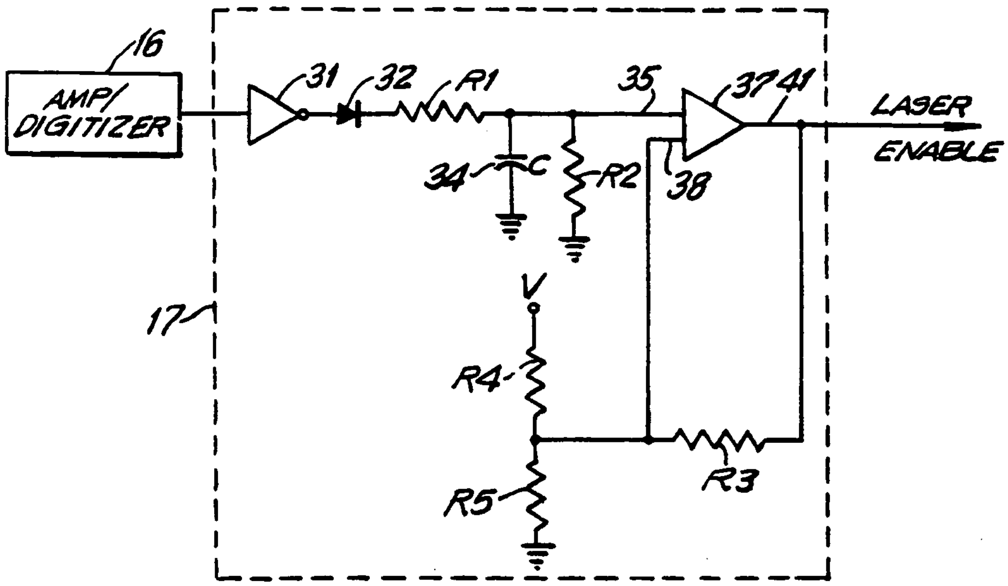

16
AMP/
DIGITIZER
31
32
R1
35
37
41
LASER
ENABLE
34
C
R2
38
V
17
R4
R3
R5

FIG.4

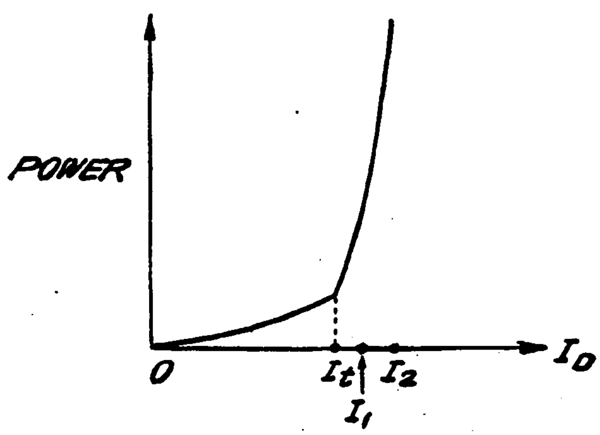

POWER
0
It
I2
I1
ID

FIG.5

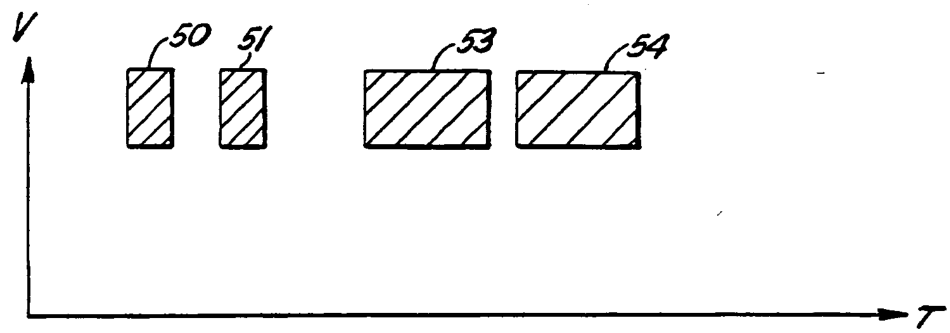


FIG.6(a)

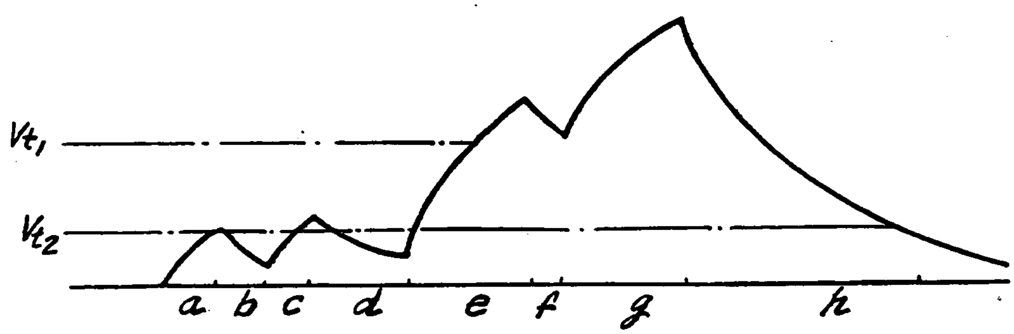


FIG.6(b)

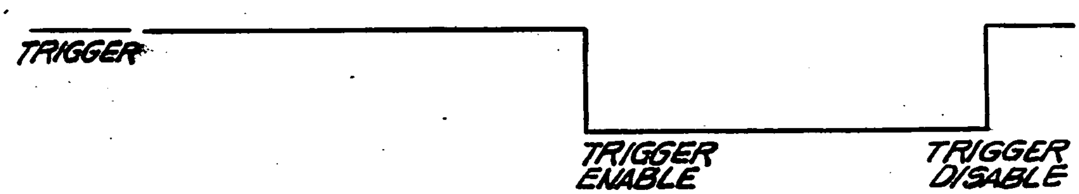


FIG.6(c)